E. Update of NCHRP Report 230

By: Hayes Ross, Texas Transportation Institute

I appreciate the opportunity to tell you a little bit about the effort we are undertaking to update the NCHRP Report 230. I want to thank John Viner for doing a great job in giving you the background for NCHRP Report 230 because that leads directly to the things I am going to talk about. When Harry said that I am going to talk about the future contents of the update, I'm not sure if that is the right word because what I am going to talk about are proposals that have been put forward, but by and large are certainly not firm at this stage. We are still going through the process of trying to reach a consensus on all of these real tough issues that we are trying to address in the update. So, I want you to keep in mind that what I am going to show you are primarily proposed changes that have been put forward. There is some basis for them. We have had a meeting of the panel that is advising the researchers on the project. We had a meeting 6 months ago to review some of these issues and try to reach a consensus on how we are to address them.

Project Scheduling

NCHRP Project 22-7 (update of *Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances*) is being conducted by the Texas Transportation Institute (TTI) with Dynatech Engineering as a subcontractor. Jarvis Michie, who had worked on the development of NCHRP Report 230 and its predecessor, will be working with us on the project.

The scheduled duration of the project is from June 1, 1989, to November 30, 1991, though it appears that it might take a little longer. The objective of this study is to update the recommended procedures for the safety performance evaluation of both temporary and permanent highway appurtenances in such a manner as to reflect advances in technology and to accommodate current and anticipated roadway and vehicle characteristics.

The project consists of six tasks to be performed in two phases. Phase I is to develop a comprehensive list of topics to be examined, evaluate the relative importance of each topic, and prepare an interim report; Phase II consists of writing various drafts and producing the final report.

The first phase is complete; we have developed the comprehensive list of topics to be examined. We have evaluated those, and we have prepared an interim report that was presented to the NCHRP panel in June, 1990. We are now into Phase II and we are almost finished with Task 4, which is the preparation of the first and second drafts of the update. We are scheduled to present the first draft to the panel within the next couple of months. After that, we will make whatever revisions are necessary and then prepare a second draft shortly thereafter; this second draft will be submitted to the highway safety community in general. We anticipate sending it out to upwards of 100 people for comments and review. I don't look forward to that because I am sure each person will have his or her own ideas as to how this update should be formulated; but nonetheless, we do want to make a sincere effort to try to develop a document that truly represents the consensus of the highway safety community.

In an effort to involve the international community, Mr. Thomas Turbell has been included as a panel member. We in the United States are making a conscious effort to try to harmonize our efforts with those of other countries.

Major Changes

There are some major changes that are proposed for the update. The first involves test vehicles. Next, as planned, the update will incorporate three features that were not covered in NCHRP Report 230. The contents and number of test matrices have changed drastically. Finally, the other change that we are considering involves the evaluation criteria. You have heard about NCHRP Report 230 from John's talk; I will try to tell you what we are proposing for the update.

Longitudinal Barriers

We will, of course, maintain guidelines for testing longitudinal barriers. I will talk later about test matrices and test conditions that are categorized in terms of severity levels. For longitudinal barriers, it is being proposed that we have six severity levels and six test matrices. Within the longitudinal barrier area, it is planned that the update will be applicable to all types of longitudinal barriers, including bridge railings, median barriers, and roadside barriers. Now, as you will see, there are some differences between what has been proposed for the update and what Jim Hatton assumed with regard to bridge railings. So, even within this country we have problems harmonizing. By no means are we firm with all of these recommendations; we are still in the review and evaluation process. As a matter of fact, we are having a meeting in the morning to explore common ground between what has been proposed for bridge railings and what we are proposing for barriers in general.

Within the longitudinal barrier area, guidelines will be given for testing the "length of need" or the "standard portion of the barrier." Then, the other part of the longitudinal barrier problem deals with where you connect it to another barrier with a different stiffness, going through a transition region. There are other parts of longitudinal barriers, but they are addressed in other areas.

Terminals and Crash Cushions

Of course, you have to terminate a longitudinal barrier, and the treatment of those terminals is of the utmost importance. Up to now, we have tested terminals differently from any other feature; one of the recommendations for the update was that we try to incorporate guidelines on evaluating terminals with crash cushions.

Within the terminal and crash cushion area, there are two subdivisions—although this is not without controversy either. We have terminals and crash cushions with what we call "redirective" capability. That is, if you hit them anywhere along the side, they are expected to redirect the vehicle; we also have inertial crash cushions that have no redirectional capability. We cannot expect those to perform as redirective devices. The big question is, "Are we ready to basically prohibit the use of anything other than redirective crash cushion devices?" This is the big question we are trying to address within the NCHRP Report 230 update.

Support Structures

The next area is support structures, traffic control devices, and breakaway utility poles. These have all been lumped together. I guess I didn't mention that under terminals and crash cushions, we are basically talking about three severity levels, which I will talk more about. Support structures have two severity levels (levels 2 and 3)—again, I will define what these are.

Truck-Mounted Attenuators

Truck-mounted attenuators (TMAs) are something new, at least to the detail that is planned for the update. TMAs are crash cushion devices placed behind trucks. They are used as shadow vehicles in moving operations primarily on the construction or maintenance activity. Two severity levels are proposed for TMAs.

Geometrical Features

Finally, the update will address, in a general fashion, testing of geometrical features such as driveway slopes or safety treatment of drainage structures, such as ditches or embankments.

Test Vehicles

Within the test matrices we have proposed, we identify two basic test matrices; the lower would involve test speeds of 45 mph, and the upper would involve test speeds of 60 mph. Two basic types of test vehicles are proposed, as shown in Table 1. The first one is a small automobile, with a minimal weight of 1,900 lb (about 863 kg).

TABLE 1 PROPOSED TEST VEHICLES

BASIC
V1—1,900 ± 100 lb (863 kg) car
V1—4,500 ± 200 lb (2,043 kg) pickup truck
SUPPLEMENTARY
SV1—1,600 ± 100 lb (726 kg)
SV2—18,000 lb (8,172 kg) single-unit truck (weight tolerances TBD)
SV3—80,000 lb (36,320 kg) tractor-van trailer (weight tolerances TBD)
SV4—80,000 lb (36,320 kg) tractor-tank trailer (weight tolerances TBD)

There is some debate over whether to maintain the current 1,800-lb vehicle or go to a 1,900-lb vehicle. The rationale for choosing the 1,900-lb vehicle is that it will be much easier to purchase. There are few sub-1,800-lb cars. The breakdown, as far as the percentage goes for automobiles weighing less than 2,000 lb, is about 3 percent of the automobile population. Cars weighing less than 1,800 lb represent less than 1½ percent of the automobile population. So, it has been proposed that the 1,800- to 2,000-lb range be considered for the small-car test vehicle.

Cars that are within the 1,800- to 2,000-lb category include the Yugo, the Toyota Tercel, the Honda CRX, and the Dodge Colt. The trend in small-car design in the United States is to start out small and then grow with succeeding model years. This trend was followed by the Honda Civic, widely used in small-car tests, which now weighs in excess of 2,000 lb. The Honda CRX is growing; it weighs almost 2,000 lb now. So, this is a problem in standardization.

As far as cars weighing less than 1,800 lb, currently in the United States, there is the GEO Metro (it has been out 2 years), Ford Festiva (which is the most popular of all the sub-1,800-lb cars here in the United States), and the Suzuki Swift (which was the Chevrolet Sprint until Chevrolet quit making it and Suzuki started selling it). I think that Suzuki was making the Sprint all along, but when Chevrolet started making the GEO and got out of the Sprint business, Suzuki picked it up.

A major change is proposed for the SV2 vehicle—not in weight, but in type. Sales data in the United States for the last 10 years shows an increasing use of what are termed "light-duty" vehicles. These are pickup trucks, vans, recreational vehicles, and vehicles like Blazers and Broncos. As a matter of fact, the statistics indicate that these vehicles represent between 15 and 20 percent of the population of the car and light-duty truck category. It was felt that this amount was significant, and that we could no longer overlook these vehicles. Furthermore, the 4,500-lb automobile sedan no longer exists in this country, except for the luxury car, which the testing agencies cannot afford to buy.

So, these two factors suggest selecting something other than a 4,500-lb test car. What has been proposed is a pickup truck. For most of the pickup trucks that are in use, this weight would be representative of a 3/4-ton pickup truck. However, there may be a trend for the 1/2-ton pickups to become larger.

Now, as we will see with the test matrices, we have two basic tests and then four supplementary tests, and the supplementary vehicles are as indicated. As far as very small automobiles, it is being proposed that something be done like NCHRP Report 230 did; that is, include a very small vehicle in the recommendation, but tests with it would be optional. That's the SV1 vehicle, and it would weigh 1,600 ± 100 lb. The SV2, SV3, and SV4 vehicles are all trucks, heavy-duty, and high-performance vehicles.

The SV2 is an 18-kip single-unit truck that we have gained some experience with through bridge rail testing. The SV3 is an 80,000-lb tractor-trailer, a fully loaded van trailer that we have also tested and learned its properties. Finally, if you want the ultimate in barrier design, you would use an 80,000-lb tractor tank-trailer truck.

Crash Severity Levels

As shown in Table 2, six severity levels have been proposed for the update. The first one would be a low-speed, low-service-level requirement. It would have potential application in some urban areas, low-speed streets, and perhaps some very low-speed work zone operations. The test speeds would be 20 and 30 mph.

TABLE 2 PROPOSED SEVERITY LEVELS

SL-1	Supplementary or optional Severity level for special minimal service requirements
SL-2 SL-3	Basic severity levels for most service requirements
SL-4 SL-5 SL-6	Supplementary or optional severity levels for special higher-service requirements

Levels SL-2 and SL-3 are referred to as the basic severity levels, and would be applicable for most service requirements at test speed of 45 and 60 mph, respectively. The final three levels are again supplementary; they lead to the high-service-level requirements.

Most features to be addressed in the update will be tested at one, two, or three severity levels. The only feature that all six severity levels would apply to is the longitudinal barrier.

Matrix Format

In NCHRP Report 230, all features were combined into one test matrix table. It is being proposed here that we separate these out and that we have test matrices that are feature dependent. Table 3 presents the proposed test matrices for longitudinal barriers. In the left column are the six severity levels; in the next column is the barrier section; the next would be the test designation, and then the impact point and evaluation criteria.

TABLE 3 TEST MATRIX FOR LONGITUDINAL BARRIERS

Severity Level	Barrier Section	Test Designation	Impact Conditions[c]			Impact Point	Evaluation Criteria[e] (See Table V-1)
			Vehicle	Nominal Speed (km/hr)	Nominal Angle, θ (deg)		
1 (Supplementary)	Length of Need	1-10	V1	48	20	(b)	A,D,F,H,I,(J),K,M
		S1-10[a]	SV1	48	20	(b)	A,D,F,H,I,(J),K,M
		1-11	V2	48	25	(b)	A,D,F,K,L,M
	Transition	1-20	V1	48	20	(b)	A,D,F,H,I,(J),K,M
		S1-20[a]	SV1	48	20	(b)	A,D,F,H,I,(J),K,M
		1-21	V2	48	25	(b)	A,D,F,K,L,M
2 (Basic - Lower Speed)	Length of Need	2-10	V1	72	20	(b)	A,D,F,H,I,(J),K,M
		S2-10[a]	SV1	72	20	(b)	A,D,F,H,I,(J),K,M
		2-11	V2	72	25	(b)	A,D,F,K,L,M
	Transition	2-20	V1	72	20	(b)	A,D,F,H,I,(J),K,M
		S2-20[a]	SV1	72	20	(b)	A,D,F,H,I,(J),K,M
		2-21	V2	72	25	(b)	A,D,F,K,L,M
3 (Basic - High Speed	Length of Need	3-10	V1	97	20	(b)	A,D,F,H,I,(J),K,M
		S3-10[a]	SV1	97	20	(b)	A,D,F,H,I,(J),K,M
		3-11	V2	97	25	(b)	A,D,F,K,L,M
	Transition	3-20	V1	97	20	(b)	A,D,F,H,I,(J),K,M
		S3-20[a]	SV1	97	20	(b)	A,D,F,H,I,(J),K,M
		3-21	V2	97	25	(b)	A,D,F,K,L,M
4 (Supplementary)	Length of Need	4-10	V1	97	20	(b)	A,D,F,H,I,(J),K,M
		S4-10[a]	SV1	97	20	(b)	A,D,F,H,I,(J),K,M
		4-11[d]	V2	97	25	(b)	A,D,F,K,L,M
		4-12	SV2	81	15	(b)	A,D,G,K,M
	Transition	4-20	V1	97	20	(b)	A,D,F,H,I,(J),K,M
		S4-20[a]	SV1	97	20	(b)	A,D,F,H,I,(J),K,M
		4-21[d]	V2	97	25	(b)	A,D,F,K,L,M
		4-22	SV2	81	15	(b)	A,D,G,K,M
5 (Supplementary)	Length of Need	5-10	V1	97	20	(b)	A,D,F,H,I,(J),K,M
		S5-10[a]	SV1	97	20	(b)	A,D,F,H,I,(J),K,M
		5-11[d]	V2	97	15	(b)	A,D,F,K,L,M
		5-12	SV3	81	15	(b)	A,D,G,K,M
	Transition	5-20	V1	97	20	(b)	A,D,F,H,I,(J),K,M
		S5-20[a]	SV1	97	20	(b)	A,D,F,H,I,(J),K,M
		5-21[d]	V2	97	15	(b)	A,D,F,K,L,M
		5-22	SV3	81	15	(b)	A,D,G,K,M
6 (Supplementary)	Length of Need	6-10	V1	97	20	(b)	A,D,F,H,I,(J),K,M
		S6-10[a]	SV1	97	20	(b)	A,D,F,H,I,(J),K,M
		6-11[d]	V2	97	25	(b)	A,D,F,K,L,M
		6-12	SV4	81	15	(b)	A,D,G,K,M
	Transition	6-20	V1	97	20	(b)	A,D,F,H,I,(J),K,M
		S6-20[a]	SV1	97	20	(b)	A,D,F,H,I,(J),K,M
		6-21[d]	V2	97	25	(b)	A,D,F,K,L,M
		6-22	SV4	81	15	(b)	A,D,G,K,M

[a] Test is optional. See Section III-A.
[b] See Figure III-1 for impact point.
[c] See Section III-C for tolerences on impact conditions.
[d] Test may be optional. See Section III-B-1.
[e] Criteria in parenthesis are optional.

Impact Point

For the impact point, a change is being incorporated. In NCHRP Report 230, recommendations on impact point are specific. For a longitudinal barrier, an impact point midway between posts on the length of need, and at a specific distance upstream from the rigid barrier in a transition are specified. We have, during the course of testing at TTI, shown in most cases that this is certainly not the critical impact point in terms of the potential for wheel snag or for vehicular pocketing. That's one of the basic reasons for running these tests, to try to determine what the weaknesses are in these systems. We are making an effort to provide guidelines on where you should impact a longitudinal barrier as a function of its stiffness, geometric properties, and the type of test vehicle. So, we will refer to Figure 2 for the impact location, which in turn, refers to another section of the update on how you actually determine where the impact point should be.

Longitudinal Barrier Strength Tests

I think the interest of the international community here today is primarily in longitudinal barriers, and I will emphasize that in my presentation. If I have time, I'll talk briefly about the proposals for crash cushions and other devices, but I did want to spend a little bit more time on the implications our proposal has on longitudinal barriers.

The proposed strength test for longitudinal barriers for these six severity levels is shown in Table 4. The vehicle for the first three levels would be the 4,500-lb pickup truck. For the last three levels, it would be in increasing order for the larger trucks. The SV2 is the 18-kip truck; the SV3 is the 80,000-lb tractor-trailer van; and the SV4 is the tanker. The first three SLs would be at 25-degree approaches at speeds from 30 to 60 mph. Remember, levels 2 and 3 are what we are recommending as the basic test matrices for all features, longitudinal barriers included. Level 3 corresponds approximately to what we have now in NCHRP Report 230 for the minimum test matrix.

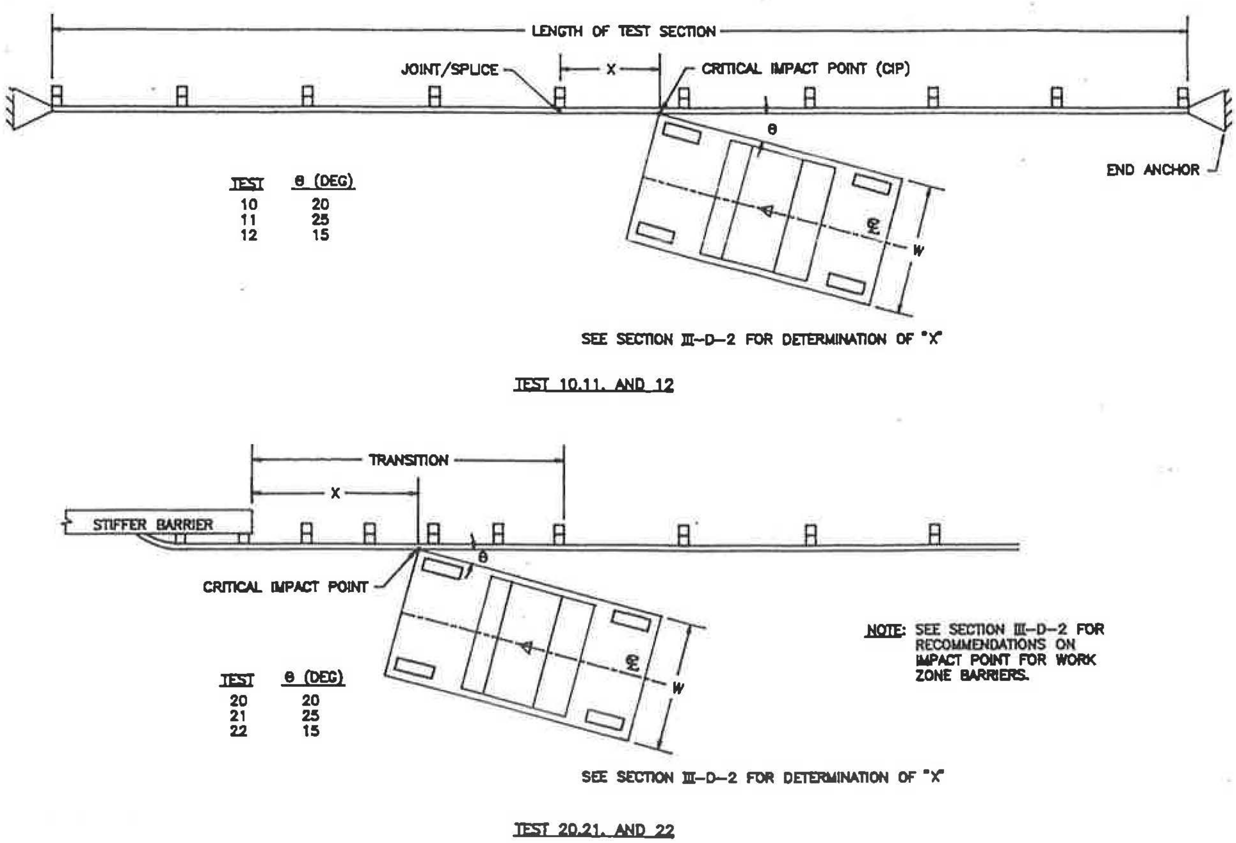


FIGURE 2 Geometry for longitudinal barrier crash tests 10-12 and 20-22.

TABLE 4 PROPOSED STRENGTH TESTS FOR LONGITUDINAL BARRIERS

		Impact Conditions		
Severity Level	Vehicle	Nominal Speed (mph)	Nominal Speed (km/hr)	Nominal Angle (deg)
1	V2	30	48	25
2	V2	45	72	25
3	V2	60	97	25
4	SV2	50	81	15
5	SV3	50	81	15
6	SV4	50	81	15

Table 5 presents approximate barrier heights required for each of the six severity levels. These numbers were obtained from Dr. Hirsch. They are primarily for rigid barriers, bridge-rail-type, and do not take flexibility into account. If you look at SL1, which was 30 mph, 25 degrees, with the pickup truck, a barrier about 20 in. (51 cm) high is indicated. For SL6, a barrier 90 in. (229 cm) tall is indicated. So, you can see up through SL5 there is a fairly uniform differential between the requirements. A big jump occurs from SL5 to SL6 because of the unstable nature of the tanker truck.

TABLE 5 APPROXIMATE BARRIER HEIGHTS NEEDED FOR LONGITUDINAL BARRIERS FOR PROPOSED SEVERITY LEVELS (HIRSCH)

Severity Level	Minimum Height (in.)	Minimum Height (cm)
1	20	51
2	24	61
3	27	69
4	32	81
5	42	107
6	90	229

Test Matrix for Terminals and Crash Cushions

Table 6 presents one of the three tables for the crash cushion test matrices. Again, we are proposing Severity Levels 1, 2, and 3 for these devices. Table 6 deals with 45-mph impacts. Terminals and redirective crash cushions are broken out from nonredirective crash cushions, as shown at the bottom of Table 6. Furthermore, in relation to NCHRP Report 230 we are adding additional tests.

Figure 3 shows some of the impact conditions proposed for terminals and redirective crash cushions. Test 30 would an off-center small car test, the off-set being one-fourth of the width of the vehicle. The second test would be the pickup truck, head-on. The next two tests, which are new tests, are angled hits on the end of the treatment with both the small car and the pickup.

Within the terminal category, we also have further subcategories. Some of our devices are designed so that if you hit them on or near the end, the vehicle is allowed to penetrate and go behind the longitudinal barrier. Other end treatments do not do this; they have redirective capabilities right up to the end of the terminal. So, this creates complications as far as additional testing we have to consider. For a gating device there are two tests that would be performed, as shown in Figure 4, and they are a little different from what was in NCHRP Report 230. The first test is at the beginning of what we call the "length of need," where direction is expected and another test with the small car midway between that point and the end of the terminal.

The tests shown in the lower part of Figure 4 are for nongating devices. I know a lot of you are thinking that you could never afford to develop terminals or crash cushions anymore if you have to run all these tests. I am sympathetic to that notion. I am just not sure how we are going to resolve it. For now, we are proposing two tests at the beginning of the length of need for nongating terminals with both the small and large car, and another test at the critical impact point along the cushion.

If the terminal device or crash cushion will be used in a median area where it can be impacted from both sides, it is proposed that a "reverse-hit" test be conducted with the pickup as indicated at the top of Figure 5. If it is used as a roadside device, but again could be hit from the reversed direction—not the reverse side—then the lower test would be conducted.

Test Matrix for Support Structures

Table 7 shows the proposed test matrices for support structures, traffic control devices, and breakaway utility poles. Traffic control devices are a new set of features that are being considered. All of these tests are with the small automobile.

TABLE 6 TEST MATRIX FOR TERMINALS AND CRASH CUSHIONS

Severity Level	Feature	Test Designation	Impact Conditions[c]			Impact Point	Evaluation Criteria[g] (See Table V-1)
			Vehicle	Nominal Speed (km/hr)	Nominal Angle, θ (deg)		
2 (Basic - Lower Speed)	Terminals and Redirective Crash Cushions	2-30[e]	V1	72	0	(b)	C,D,F,H,I,(J),K,N
		S2-30[a,e]	SV1	72	0	(b)	C,D,F,H,I,(J),K,N
		2-31	V2	72	0	(b)	C,D,F,H,I,(J),K,N
		2-32[d]	V1	72	15	(b)	C,D,F,H,I,(J),K,N
		S2-32[a,d]	SV1	72	15	(b)	C,D,F,H,I,(J),K,N
		2-33[d]	V2	72	15	(b)	C,D,F,H,I,(J),K,N
		2-34	V1	72	20	(b)	A,C,D,F,H,I,(J),K,N
		S2-34[a]	SV1	72	20	(b)	A,C,D,F,H,I,(J),K,N
		2-35	V2	72	25	(b)	A,D,F,K,L
		2-36	V2	72	25	(b)	A,D,F,K,L
		2-37[d]	V2	72	20	(b)	A,D,F,H,I,(J),K,N
	Nonredirective Crash Cushions[f]	2-40[e]	V1	72	0	(h)	C,D,F,H,I,(J),K
		S2-40[a,e]	SV1	72	0	(h)	C,D,F,H,I,(J),K
		2-41	V2	72	0	(h)	C,D,F,H,I,(J),K
		2-42	V1	72	15	(h)	C,D,F,H,I,(J),K,N
		S2-42[a]	SV1	72	15	(h)	C,D,F,H,I,(J),K,N
		2-43	V2	72	15	(h)	C,D,F,H,I,(J),K,N
		2-44	V2	72	20	(h)	C,D,F,K,L

[a] Test is optional. See Section III-A.
[b] See Figure III-2 for impact point.
[c] See Section III-C for tolerances on impact conditions.
[d] Test may be optional. See Section III-B-2.
[e] See discussion in Section III-B-2 relative to tests 30 and 40.
[f] See discussion in Section III-B-2 relative to nonredirective crash cushions.
[g] Criteria in parenthesis are optional.
[h] See Figure III-3 for impact point.

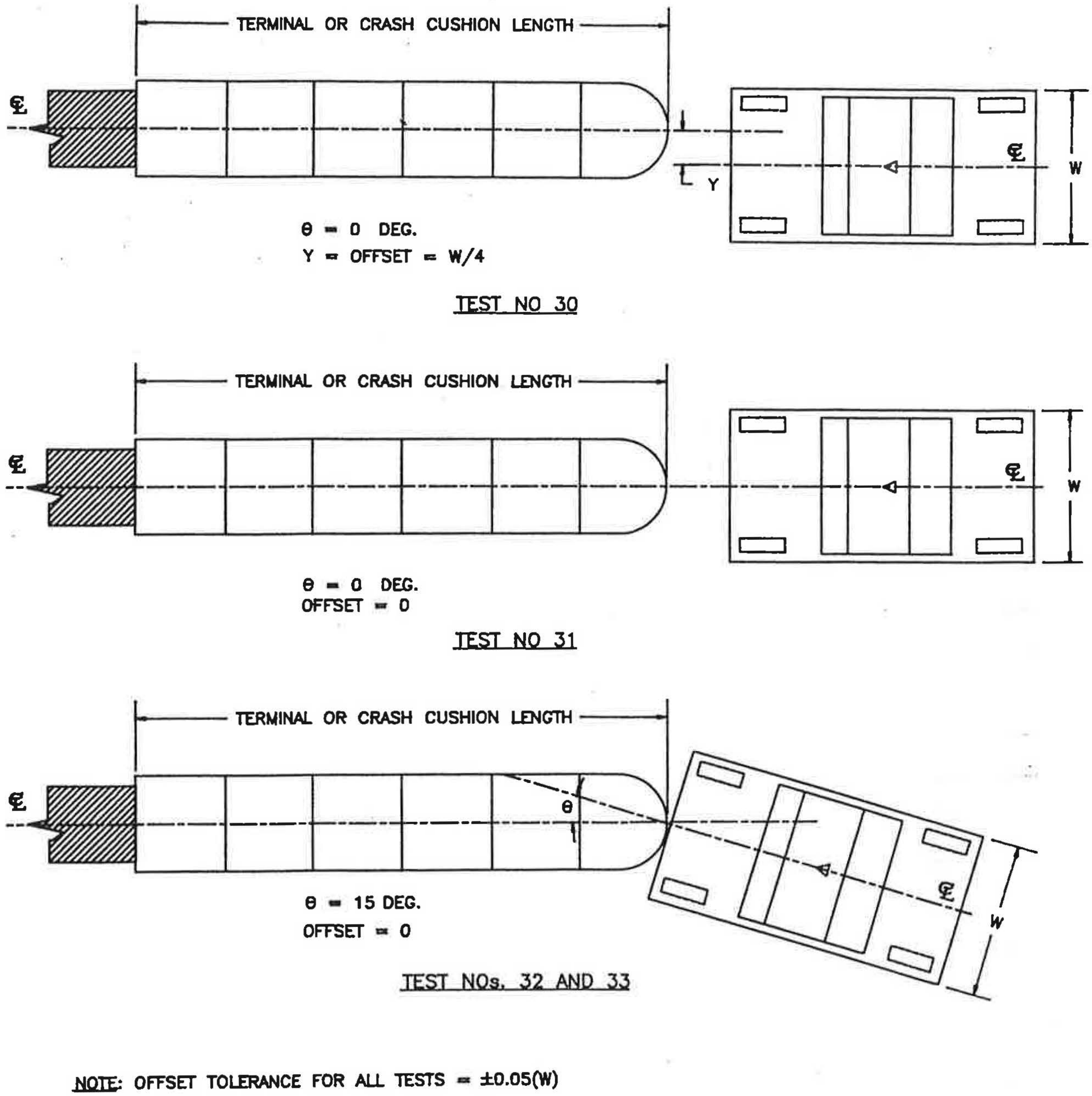
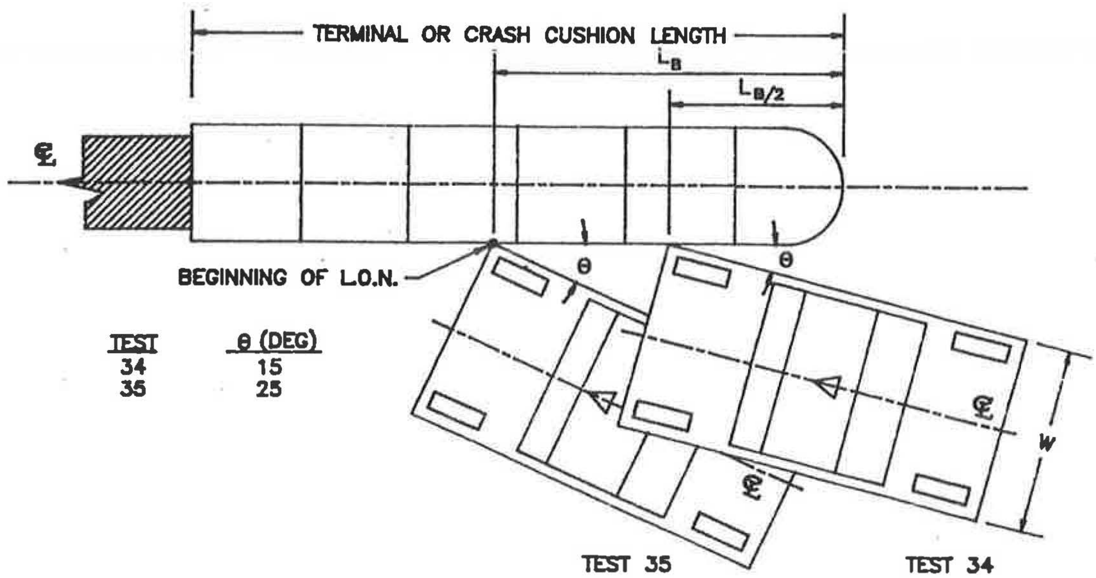
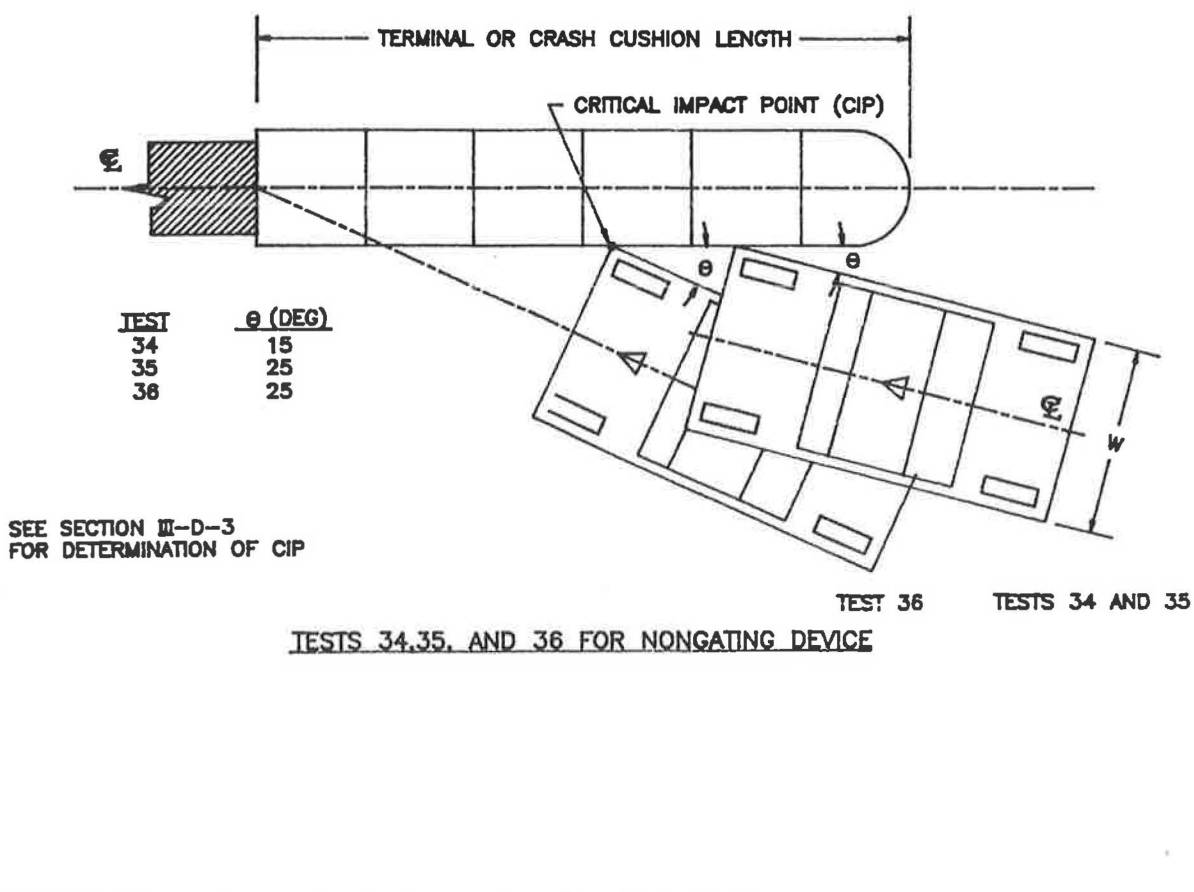


FIGURE 3 Geometry of terminal or crash cushion Tests 32-33.

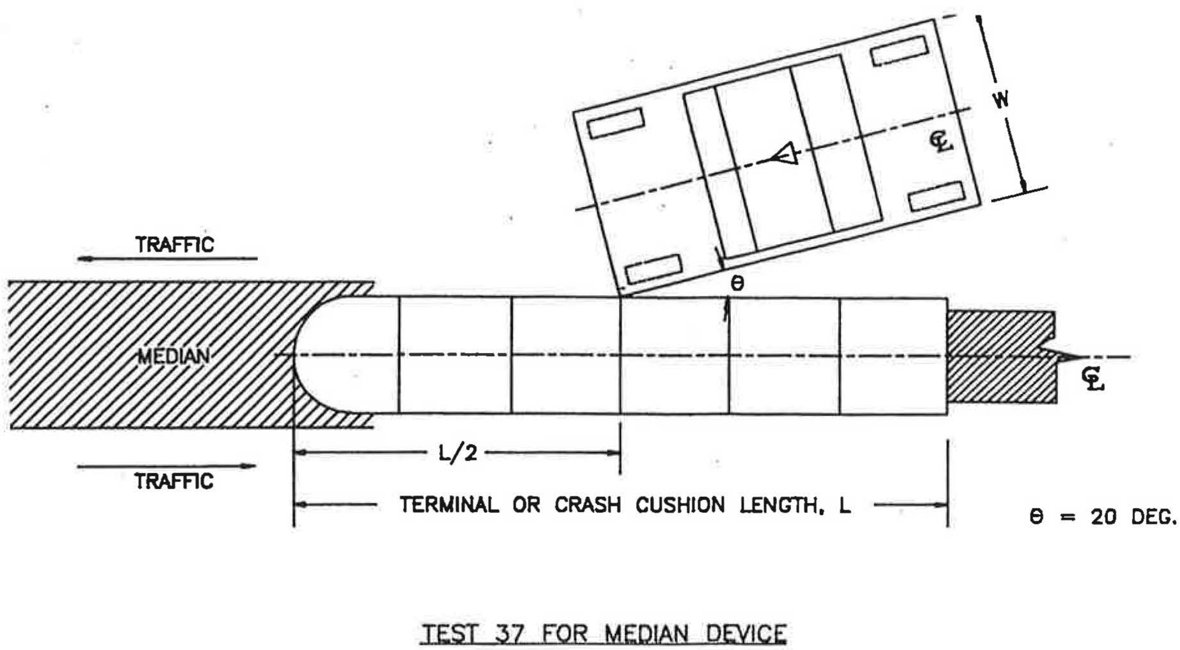


TEST 34 AND 35 FOR GATING DEVICE



TESTS 34,35, AND 36 FOR NONGATING DEVICE

FIGURE 4 Geometry for terminal or crash cushion Tests 34-36.



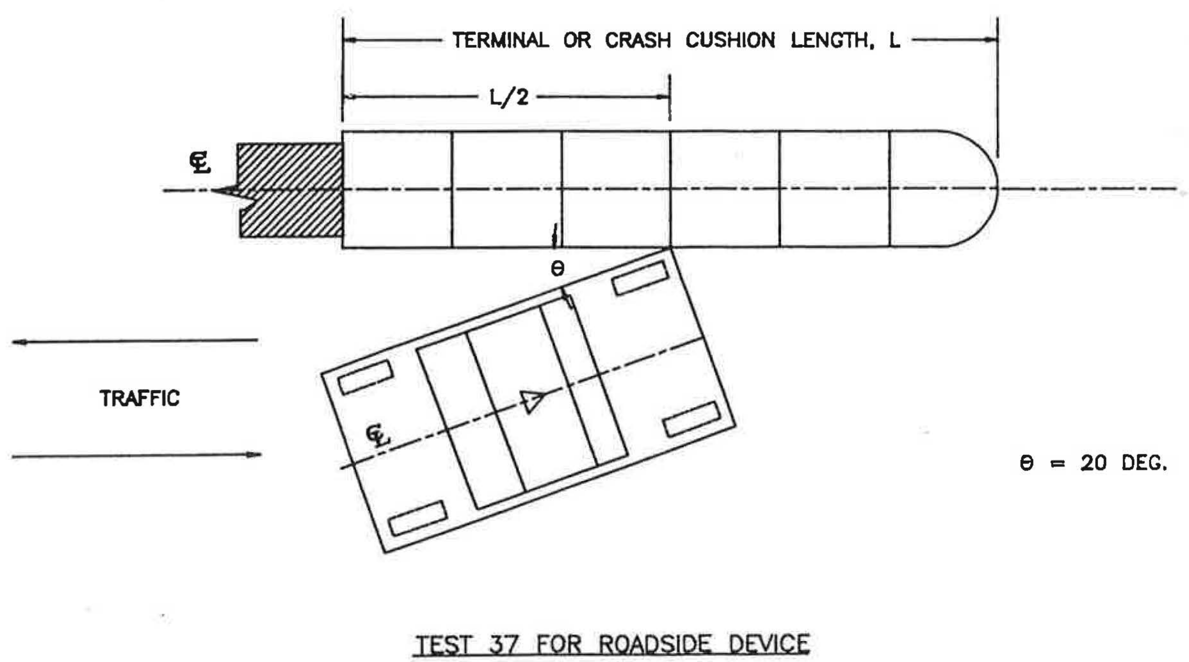


FIGURE 5 Geometry for median and roadside device crash Test 37.

TABLE 7 TEST MATRIX FOR SUPPORT STRUCTURES, TRAFFIC CONTROL

Severity Level	Feature	Test Designation	Impact Conditions[c]			Impact Point	Evaluation Criteria[d] (See Table V-1)
			Vehicle	Nominal Speed (km/hr)	Nominal Angle, θ (deg)		
2 (Basic - Lower Speed)	Support Structures	2-60	V1	32	0-20	(b)	B,D,F,H,I,(J),K,N
		S2-60[a]	SV1	32	0-20	(b)	B,D,F,H,I,(J),K,N
		2-61	V1	72	0-20	(b)	B,D,F,H,I,(J),K,N
		S2-61[a]	SV1	72	0-20	(b)	B,D,F,H,I,(J),K,N
	Traffic Control Devices	2-70	V1	32	0-20	(b)	B,D,E,F,H,I,(J),K,N
		S2-70[a]	SV1	32	0-20	(b)	B,D,E,F,H,I,(J),K,N
		2-71	V1	72	0-20	(b)	B,D,E,F,H,I,(J),K,N
		S2-71[a]	SV1	72	0-20	(b)	B,D,E,F,H,I,(J),K,N
	Breakaway Utility Poles	2-80	V1	48	0-20	(b)	B,D,F,H,I,(J),K,N
		S2-80[a]	SV1	48	0-20	(b)	B,D,F,H,I,(J),K,N
		2-81	V1	72	0-20	(b)	B,D,F,H,I,(J),K,N
		S2-81[a]	SV1	72	0-20	(b)	B,D,F,H,I,(J),K,N
3[f] (Basic - High Speed)	Support Structures	3-60	V1	32	0-20	(b)	B,D,F,H,I,(J),K,N
		S3-60[a]	SV1	32	0-20	(b)	B,D,F,H,I,(J),K,N
		3-61	V1	97	0-20	(b)	B,D,F,H,I,(J),K,N
		S3-61[a]	SV1	97	0-20	(b)	B,D,F,H,I,(J),K,N
	Traffic Control Devices	3-70[e]	V1	32	0-20	(b)	B,D,E,F,H,I,(J),K,N
		S3-70[a,e]	SV1	32	0-20	(b)	B,D,E,F,H,I,(J),K,N
		3-71	V1	97	0-20	(b)	B,D,E,F,H,I,(J),K,N
		S3-71[a]	SV1	97	0-20	(b)	B,D,E,F,H,I,(J),K,N
	Breakaway Utility Poles	3-80	V1	48	0-20	(b)	B,D,F,H,I,(J),K,N
		S3-80[a]	SV1	48	0-20	(b)	B,D,F,H,I,(J),K,N
		3-81	V1	97	0-20	(b)	B,D,F,H,I,(J),K,N
		S3-81[a]	SV1	97	0-20	(b)	B,D,F,H,I,(J),K,N

[a] Test is optional. See Section III-A.
[b] See discussion in Section III-B-3 relative to impact point.
[c] See Section III-C for tolerances on impact conditions.
[d] Criteria in parenthesis are optional.
[e] See discussion in Section III-B-3 relative to test 70.
[f] See discussion in Section III-B-3 relative to severity level 3.

Test Matrix for Truck-Mounted Attenuators

The TMA test may be of interest to some of you. As shown in Table 8, two basic tests are proposed. A major change, if adopted, would be the high-speed test for TMAs. Up to now TMAs have been designed basically for 45-mph impacts. There may be some instances where a high-speed 60-mph TMA is needed. With reference to Figure 6, the first two would involve both the large and small hit centered on the rear of the TMA. The last two would involve the pickup truck. The third test would be off-centered, straight on; the last test would be off-centered at an angle.

Evaluation Criteria

The last thing I have to talk briefly about is evaluation criteria. Again, I think John covered these items real well as far as NCHRP Report 230. As far as structural adequacy, we don't propose any major changes to that. Under the occupant risk, we propose to retain the flail space model concept. We're debating whether or not to incorporate some refinement in the procedures that are used to calculate occupant impact velocity. The current procedure does not properly account for angular rotations of the vehicle during impacts with longitudinal barriers. Maybe we should improve that. In the update, we are going to maintain the unrestrained occupant assumption as far as the tolerances go because about 50 percent of our citizens don't use seat belts.

The following outline summarizes the proposed changes regarding the evaluation criteria:

- Structural adequacy, no major changes
- Occupant risk;
  - Retail flail space model;

TABLE 8 TEXT MATRIX FOR TRUCK-MOUNTED ATTENUATORS

Severity Level	Test Designation	Impact Conditions[c]			Impact Point	Evaluation Criteria[e,g] (See Table V-1)	EVALUATION CRITERIA[f,g] (See Table V-1)
		Vehicle	Nominal Speed (km/hr)	Nominal Angle, θ (deg)			
2 (Basic - Lower Speed)	2-50	V1	72	0	(b)	C,D,F,H,I,(J),K	D,F,I,(J)
	S2-50[a]	SV1	72	0	(b)	C,D,F,H,I,(J),K	D,F,I,(J)
	2-51	V2	72	0	(b)	C,D,F,H,I,(J),K	D,F,I,(J)
	2-52	V2	72	0	(b)	C,D,F,H,I,(J),K	D,F,I,(J)
	2-53	V2	72	10	(b)	C,D,F,H,I,(J),K	D,F,I,(J)
3[d] (Basic - High Speed)	3-50	V1	97	0	(b)	C,D,F,H,I,(J),K	D,F,I,(J)
	S3-50[a]	SV1	97	0	(b)	C,D,F,H,I,(J),K	D,F,I,(J)
	3-51	V2	97	0	(b)	C,D,F,H,I,(J),K	D,F,I,(J)
	3-52	V2	97	0	(b)	C,D,F,H,I,(J),K	D,F,I,(J)
	3-53	V2	97	10	(b)	C,D,F,H,I,(J),K	D,F,I,(J)

[a] Test is optional. See Section III-A.
[b] See Figure III-5 for impact point.
[c] See Section III-C for tolerances on impact conditions.
[d] See discussion in Section III-B-4 relative to severity level 3.
[e] For impacting vehicle and its occupants.
[f] For supporting truck and its driver. See discussion in Section V-C.
[g] Criteria in parenthesis are optional.

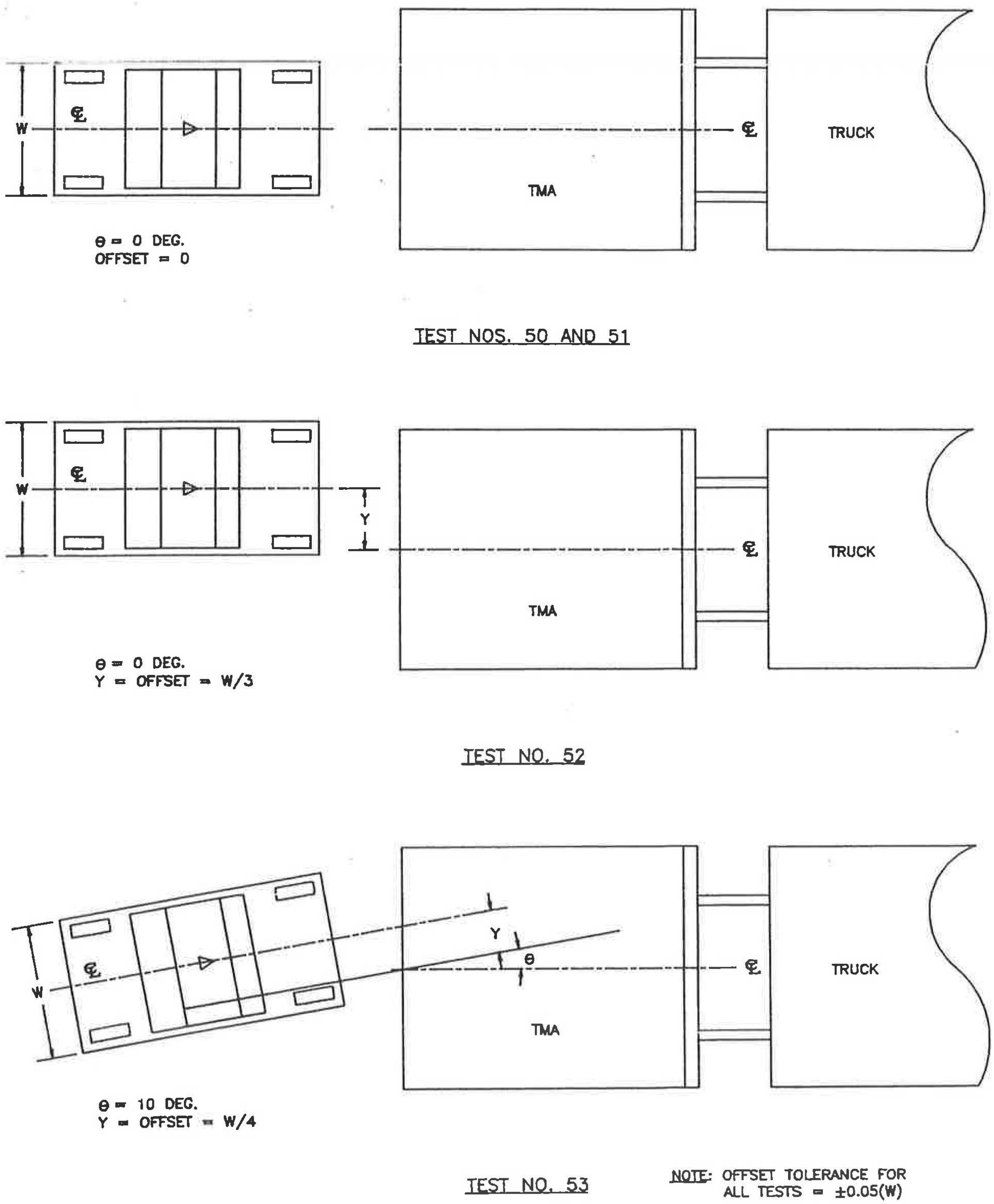


FIGURE 6 Geometry for truck-mounted attenuator crash Tests 5-53.

- — Change lateral occupant impact velocity limits to equal those for longitudinal direction barriers, crash cushions, TMAs, and breakaway utility poles; recommended 30 ft/sec (9.2 m/sec, and maximum 40 ft/sec (12.2 m/sec);
- Retain ridedown deceleration limits, recommended 15 Gs, and maximum 50 Gs;
- Retain occupant impact velocity limits for support structures and traffic control devices, maximum 16 ft/sec (4.9 m/sec); and
- Postimpact trajectory;
  - — Omit 15-mph vehicular ΔV limit;
  - — Add 40-ft/sec vehicular ΔV limit.

One of the refinements that was considered and rejected was that we not only consider updating to the calculations procedures, but that we also change the box that we have the unrestrained occupant in. In NCHRP Report 230, the box is 2 ft wide. The driver can flail to the left 1 ft or to the right 1 ft, and he can go forward 2 ft. But we all know that an unrestrained occupant is not restrained that way; there is no box in the vehicle. If you hit a barrier on the right side of the vehicle and you are the driver, you are going to flail about the front seat until you hit the right side of the vehicle. We thought about incorporating that, but the truth is, if you do that, then we have to rule out most barriers.

Experience has indicated that the numbers we are using are fairly reasonable. We do not see any evidence from the data that we have a major problem with occupant injury when we have smooth redirection, somewhat independent of impact conditions. I think we have some support for what we are doing. It may not be consistent with what might be expected from the real world. One of the changes being proposed is uniform limits for occupant impact velocities, both lateral and longitudinal. In discussions with the experts—General Motors and others—we were convinced that there were no major differences, at least within the context of the flail space calculations, for justifying lower lateral and longitudinal limits.

So, it is being proposed that the same limit be adopted for both cases—a recommended limit of 30 ft/sec, which is what NCHRP Report 230 has with the factor of safety, and a maximum of 40 ft/sec, the limit in NCHRP Report 230 with no factor of safety. We propose to retain the ridedown acceleration limits. We also propose to retain the occupant impact velocity limits for support structures.

Finally, a change is being proposed for the post-impact trajectory. In tests of most longitudinal barriers, we cannot meet the 15-mph velocity change requirement of NCHRP Report 230. So, let us add a 40-ft/sec velocity change limit that is consistent with the occupant risk criteria, and yet reasonable in terms of vehicle behavior after impact.